DEPARTMENT *of*
PRIMARY INDUSTRIES,
WATER *and* ENVIRONMENT

Tasmania

Ecological flow requirements for the George River

Claire McKenny and Colin Shepherd
Aquatic Ecologists
Water Assessment Section
DPIWE.

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TABLE OF CONTENTS

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A Glossary of Terms

base flows	flow in a river composed of water from deep subsurface and groundwater sources with no contribution from precipitation
broadwater	long, broad run with slow water flow
IFIM	Instream Flow Incremental Methodology
macrophytes	large aquatic plant
macroinvertebrates	invertebrate (without a backbone) animals which can be seen with the naked eye
riparian vegetation	vegetation on the banks of streams and rivers
sinuosity	degree of “bendiness” of a river (ratio of valley length: river length)
snags	instream woody debris
pools	deep, still water , usually within the main river channel
riffles	areas of fast moving broken water
run	unbroken, moving water
substrate	the structural elements of the river bed; boulder, cobble etc.
T. G. R.	Tasmap Grid Reference
WUA	Weighted Useable Area, or the amount of useable habitat available in the river for a species

B Executive Summary

This report details the ecological assessment of flow requirements for the George River and forms part of the process of developing a water management plan for the catchment. Both community and State technical values were identified as part of the assessment process and the ecological values were used to focus the ecological flow assessment.

Ecological values specifically targeted included:

- to maintain sufficient habitat for jollytail (*Galaxias maculatus*), shortfinned eels (*Anguilla australis*) and brown trout (*Salmo trutta*);
- to maintain sufficient habitat for macroinvertebrate populations found in the George River.

A risk analysis was performed to provide (1) a series of options for future water management plans; and (2) the ecological risk of failure in not achieving these flows for each of these values. This was achieved by determining the flow at which the useable habitat available to a species changes by a certain percentage, relative to that available if irrigation offtakes did not occur. The percentage changes in habitat that determined risk categories were taken from Davies and Humphries (1996). This analysis was performed for each of the key biota (fish and invertebrate species).

Other values identified, and discussed in the report include:

- to maintain fish stocks, including Australian grayling (*Prototroctes maraena*), spotted galaxiid *(Galaxias truttaceus*), jollytail (*Galaxias maculatus*) and brown trout (*Salmo trutta*);
- to protect *Phebalium daviesii* (St Helens wax flower); and
- to maintain rearing and/or spawning habitat for the spotted galaxiid*,* jollytail, grayling, lampreys (*Mordacia mordax* and *Geotria australis*), brown trout, freshwater flathead (*Pseudaphritis urvillii*), longfinned eels (*Anguilla reinhardtii*) and shortfinned eels.

Flow recommendations for the Yosts Flat reach

Flows for each risk category, Georges River, Yosts Flats reach (flow in cumecs)

Risk Category	No Risk	Moderate Risk	High Risk
Month			
December	>1.3	1.3 - 1.2	<1.2
January	>1.1	1.1 - 0.6	<0.6
February	>0.7	0.7 - 0.5	<0.5
March	>1.1	1.1 - 0.6	<0.6
April	>1.3	1.3 - 1.2	<1.2

1 Introduction

In accordance with the water reform agenda set out by the Council of Australian Governments, or COAG (ARMCANZ and ANZECC, 1996), Tasmania is currently developing water management plans for many of its major rivers. Intrinsic to this process is the requirement that a supply of water will be provided to the environment as well as to human users to maintain or improve ecosystem quality and health of river systems. For full details about the process of developing a water management plan, refer to Fuller and Read (1997) and Appendix 1. Briefly, the process involves:

- the identification of water values by the community and the State Technical Committee for Environmental Flows (a panel representing the State government's technical and scientific expertise);
- the assessment of the flow necessary to maintain these values, which includes an environmental flow assessment;
- negotiation and tradeoff of these values if required when determining a new flow management regime; and
- monitoring of both compliance and environmental benefit of the new flow regime once this is in place.

The George River occurs downstream of the confluence of its two major tributaries, the North and South George rivers, which arise in the Rattler Range in North-east Tasmania. The river flows into Georges Bay just north of St Helens. The catchment is currently not extensively developed for irrigation.

Assessment will concentrate on the low flow period between December to April, as this is when the river is suspected to be most under stress. However, the issue of non-summer flows may need attention in future if abstraction increases or there is further development of the water resource.

An important caveat to this report is that the flows recommended for each month are only appropriate for that period. Additional work will be required to identify other necessary components of the flow regime should significant developments be proposed in this catchment.

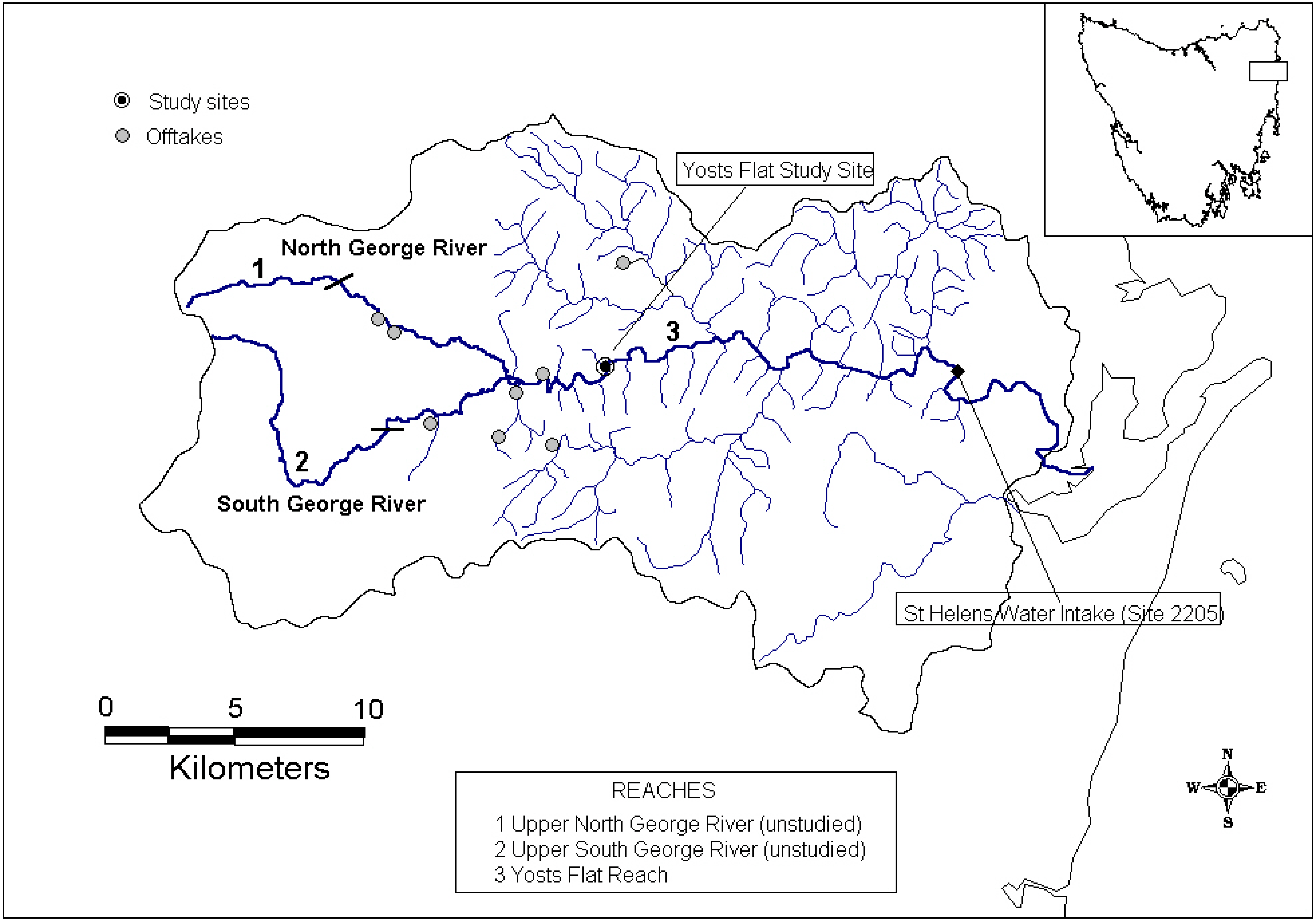
2 The George River

2.1 General Description

Both the North and South George Rivers rise at some 800m altitude and steeply fall to around 130m altitude, some two or three kilometres upstream of their confluence at Pyengana (see Figure 2.1). Both rivers are approximately 50 km long and the South George River has a catchment area of 410 km^2.

The South George River has its source in the Rattler Range and flows some 20km northwest to its confluence with the North George, which it meets as a 4th order river. The river's headwaters flow through basalt and then fall steeply through granodiorite as the St Columba Falls. Vegetation here is protected in the St Columba Falls Reserve, and consists of tall closed-forest dominated by myrtle (*Nothofagus cunninghamii*), sassafras (*Atherosperma moschatum*), dogwood (*Pomaderris apetala*) and stinkwood (*Zieria arborescens*). Understorey species include blanket leaf (*Bedfordia salicina*) and various ferns. The river then travels through granite and begins to lose gradient just upstream of the North George confluence.

Figure 2.1 Map of the George Rivers showing CWRs and study reach. Bars mark the boundaries of the representative reaches (refer to text)



The North George River is a 3rd order river which flows east through the turbidite sequences of the Mathinna Beds and then falls steeply through granodiorite and granite until it meets alluvium and talus and loses gradient. The dominant vegetation of the head of the catchment is similar to that of the catchment of the upper South George, and is largely undisturbed (Pinkard, 1980).

The George River downstream of the confluence meanders to the sea through alluvium with some outcropping granodiorite near Littlechild's Creek. Vegetation is largely cleared with small pockets of remnant open forest dominated by white gum (*E. viminalis*) and black peppermint (*E. amygdalina*), with an understorey of bull-oak (*Casuarina littoralis),* manuka (*Leptospermum scoparium*), prickly mimosa (*Acacia verticillata*) and bracken fern (*Pteridium esculentum*). Small pockets of woodland dominated by cabbage gum (*E. pauciflora*), white gum (*E. viminalis*) and swamp gum (*E. regnans*) also remain. Principal land uses are grazing, forestry, and nature conservation. Numerous old alluvial tin mines remain in the area.

At present there is little irrigation pressure on the river, with Commissional Water Rights only amounting to approximately 7 megalitres per day during the irrigation season and 26.5 megalitres of storage. Swimmers and anglers are key recreational users of the river; trout is the major fish species caught.

2.2 Site Selection

Study sites for assessing the relationship between habitat availability of key species and water discharge were selected according to the protocol of Bovee (1982). Two reaches were identified within the South George River and two in the North George River. A site on the George River downstream of the confluence of the South and North George was chosen as representative of the lower reaches of both rivers (see Figure 2.1). The top reaches of both rivers were not surveyed due to the lack of significant CWRs or other abstractions, although they will require investigation if water development of the upper catchment occurs in the future. The representative reach selected for study is described below.

2.2.1 George River, Yosts Flat Reach

The study site here is approximately 300m long and is located from Tasmap grid reference 5429700 589000 at the downstream end to 5429600 588400 at the upstream end. This site is representative of the lowest reach of the North and South George rivers. This reach starts from the end of the steeper section of both rivers (Tasmap grid reference 5427200 579800 South George, T. G. R. 5432800 577800 North George) and ends at the beginning of the tidal influence. This section of river has sequences of riffles, shallow runs and deep pools, is relatively sinuous, and has sand- and pebble-dominated substrate.

3 Values

3.1 Community Values

The community values for the George River were identified at a meeting held in South Helens on the 30th of September 1998. The values as identified and prioritised by representatives of various interest and stakeholder groups for the South George catchment are shown in Table 3.1.

Table 3.1 Community Water Values for the George River. 1 denotes highest priority, 5 the lowest

BROAD WATER VALUE CATEGORIES	SPECIFIC WATER VALUES	PRIORITISATION OF VALUES
Ecosystem	Maintain existing riparian zone in catchment streams* Maintain suitable in-stream habitat Maintain water quality Control tailings input from Anchor mine* Improve bankside erosion control* Maintain sufficient flows for fish habitat retention Maintain fish stocks Maintain drinking water quality	2 3 1 4 2 3 5 1
Consumptive and non-consumptive use	Improve on farm storage* Provide for increase of outtakes at reasonable cost* Ensure non-monopoly and speculation of water rights* Water use and licence discrepancies - maintain existing water use* Provide fair system of water allocation Maintain riparian rights (water rights)* Provide appeals tribunal for water use arguments*	4 2 1 3 3 3 1 3
3.Recreational	Maintain + improve angling values Maintain water quality and quantity for swimming	1 2
4. Aesthetic	Maintain visual quality Maintain reasonable flows over St Columba Falls Maintain + improve riparian zone quality* Improve riparian weed control*	2 1 2 3
5. Physical Landscape	Allow public consultation process in maintaining landscape values* Maintain quality of State Reserve in area of St Columba Falls* Maintain pools and other habitats in Little Childs Ck Maintain undisturbed status of headwaters Improve vegetative rehabilitation of Anchor Mine site* Protect the cultural heritage of past (historical mining and agricultural) activities*	2 1 4 1 2 3

* The maintenance or enhancement of those values marked with an asterisk were not considered to be influenced by changes in discharge or water quantity and will not be discussed further in this report.

3.2 State Technical Values

Additional values were identified for the South George River by the State Technical Panel. The panel included representatives from DPIWE, who provided advice on aquatic ecology, wetlands, geomorphology, riparian vegetation, and estuarine ecology, fisheries biology and ecology. In addition, there were environmental representatives from the Hydro-Electric Corporation and a representative from the University with relevant expertise. The values that the panel thought warranted consideration or further investigation were:

- to maintain the rare Australian grayling (*Prototroctes maraena*);
- to protect the *Phebalium daviesii* (St Helens wax flower) which is listed as endangered in the *Tasmanian Threatened Species Act 1995*; and
- to maintain rearing and/or spawning habitat for spotted galaxias (*Galaxias truttaceus*), common jollytail (*Galaxias maculatus*), Australian grayling, lampreys (*Mordacia mordax* and *Geotria australis*), brown trout (*Salmo trutta*), freshwater flathead (*Pseudaphritis urvillii*), and long and shortfinned eels (*Anguilla reinhardtii* and *Anguilla australis*).

For further information on the importance of these values refer to Section 6: Discussion.

3.3 Values Assessed

It should be noted that while water quality was identified as a community value it was not assessed. Davies and Humphries (1996) found that nutrient and turbidity levels in the South Esk River basin were primarily determined by flood flows and were not related to low flows. The same also applied to dissolved oxygen conditions in pools. The water quality risks associated with declining flows during the irrigation season were therefore not considered significant.

In summary, the values that were considered by DPIWE during the assessment of ecological requirements for flow in the South George River include:

- to maintain suitable in-stream habitat;
- to maintain sufficient flows for fish habitat retention; and
- to maintain fish stocks, including grayling, spotted galaxiid, jollytail and brown trout.

Values that were targeted for detailed and specific assessment include:

- to maintain sufficient habitat for jollytail, shortfinned eels and brown trout;
- to maintain sufficient habitat for macroinvertebrate populations found in the George River.

4 Methodology

The method used to assess the flow requirements of key species (see Table 5.2) was the Instream Flow Incremental Methodology (IFIM), originally described by Bovee (1982). In this process, the preferences of key species for velocity, depth and substrate parameters are combined with transect-derived hydrologic data at specific discharges. This data is then incorporated into a suitability index, which is a function of available depth, velocity and substrate. This suitability function is then summed over the study reach to give the weighted useable area, or WUA (refer to Jowett, 1992).

Hydraulic simulation is used to generate velocity and depth data for each transect at the discharges for which data are not available. The outcome is a plot of WUA against discharge for each species or lifestage (see Figure 5.1). An analysis of the flow levels that will provide varying degrees of risk to the ecosystem is then possible.

The software package used for this process was the RHYHABSIM (River HYdraulics and HABitat SIMulation) program developed by Jowett (1989, 1992).

4.1 Physical Habitat Data

Transects were established at the site according to the protocol detailed by Bovee (1982). Within each study reach, a number of distinct sub-reaches were identified on the basis of hydraulic characteristics and substrate. Transects were established within each of these sub-reaches, perpendicular to the channel.

At each transect, a semi-permanent datum (or header peg) was established by driving a mild steel star picket deep into the upper section of the bank. All measurements were taken perpendicular to the direction of flow, to a point on the opposite bank at a similar height above water level. Water surface elevation, relative to the elevation of the header peg, was recorded at each transect.

On the initial visits depth, average water velocity and substrate composition were measured and recorded. These measurements were taken at regular intervals evenly distributed across the channel with a minimum of 10-15 wetted points. In this way each transect was divided into regular 'cells' by collecting all data at the same distances from the header peg. Depth and velocity at 0.6 of the depth from the surface were recorded at each of these points using a pre-calibrated Pygmy current velocity meter and wading rod. Percentage substrate composition was also recorded at each location using the following categories: aquatic vegetation; mud; sand; fine gravel; large gravel; cobble; boulder and bedrock. Substrate particles were characterised by the following modified Wentworth scale:

R = Bedrock	
B = Boulder	>256 mm
C = Cobble	64 - 256 mm
P = Pebble	8 - 64 mm
G = Gravel	2 - 8 mm
S = Sand	0.06 - 2 mm
M = Silt/Mud	<0.06mm

On subsequent visits calibration gaugings were carried out at a suitable location within both study sites to determine discharge. The height of the water surface from the datum peg was measured at each transect at the same time. The data collected from these sites were entered into an Excel™ spreadsheet in the format required by the RHYHABSIM program.

4.2 Biological Data

4.2.1 Invertebrates

Seventeen invertebrate samples were taken at Yosts Flat. Sampling effort was stratified in order to fully represent the range of depth, velocity and substrate at the sites. Stratification was carried out on the combined habitat data from both sites sampled, using the methodology described by Davies et al. (1997). Sampling for macroinvertebrates was carried out by disturbing the substrate within a $1m^2$ quadrat upstream of a 250µm kick net. The preserved samples were later sub-sampled to 20% and invertebrates were identified to the lowest taxonomic level possible using the most up-to-date taxonomic keys.

The resulting habitat preference information was used for the creation of WUA-Q curves for key fish species and lifestages. Key species were selected on the basis of:

- not having rare or patchy abundance; and
- exhibiting clear preferences for depth, velocity and substrate

4.2.2 Fish

Habitat preference curves used for brown trout early young of the year, or 0+ were developed from data collected in March 1990 - 1993 by Davies & Diggle (unpublished data) and preference curves for brown trout adults were developed by Bovee (1978). Habitat preference information for shortfinned eels and jollytail were collected by Jowett and Richardson (1995).

The transfer of habitat preference curves between different catchments is regarded by many ecologists as an acceptable practice for the above species. Examination of curves for brown trout by previous workers has generally found that these curves are similar in their rise and fall between rivers both in Australia and overseas (Dr P. E. Davies, Freshwater Systems, pers. comm.). Similarly, the habitat requirements for shortfinned eels and jollytail are generally regarded as comparable between rivers (Jowett and Richardson, 1995). Given the agreement among these ecologists regarding the transfer of habitat preference information for these species, preference curves from other rivers have been adopted for use in this assessment.

4.3 Hydraulic Simulation

From the habitat data of both sites combined, and the biological samples collected, values of useable habitat area (called Weighted Useable Area or WUA) were generated in m^2/m of stream channel for each species or lifestage at a range of discharges. The protocol for generating these WUA-Q curves is that described by Jowett (1992), using the RHYHABSIM hydraulic modelling and simulation package. A single Excel™ data set, containing:

- velocity, depth and substrate data at every offset for each transect;
- locations of all water edges ;
- inter-transect distances; and
- stage-discharge relationships for each transect.

This information was used to generate velocities and depths at discharges from 0.1 to 2.0 cumec. The protocol used for the hydraulic simulation is described by Davies et al. (1997).

The generation of Weighted Useable Area to Discharge (WUA-Q) curves is detailed by Jowett (1992). Habitat preference data were combined with simulated velocity and depth data and the measured substrate data, so as to calculate habitat suitability for each cell. The values for all cells from all transects were combined to generate a species' total habitat area, or Weighted Useable Area (WUA) in m^2/m or % of stream area for the whole site for each discharge value. This process was used to generate curves of WUA as it changes with discharge for both sites, for all the key species and life stages.

4.4 Risk Analysis

The risk analysis used in this study is a modification of that developed by Davies and Humphries (1995). Risk is based upon changes in habitat (ΔWUA) relative to a reference flow. In this study the reference flows used were the median monthly flows at each site for the period 1968-1999 adjusted to account for irrigation takes (ie. the median monthly flows at each site that would have occurred without abstraction).

In this case there are 3 risk categories, and 5 variables (see Table 2). The variables include:

1. adult brown trout (*Salmo trutta*)
2. early young of the year (0+) brown trout (*Salmo trutta*)
3. jollytail (*Galaxias maculatus)*
4. shortfinned eel (*Anguilla australis*)
5. combined invertebrate taxa (see Table 5.2 for a complete list)

Table 2. Criteria for assigning risk levels to different values of change in habitat (ΔWUA) relative to the reference flow (Q_m) for the key ecological variables in this study. Derived from Davies and Humphries (1995).

Risk Category	No Risk	Moderate Risk	High Risk
Variable			
ΔWUA for trout 0+ and adults, jollytails and shortfinned eels (1-4)	>85% WUA cf Q_m	60-85% WUA cf Q_m	30-60% WUA cf Q_m
ΔWUA for individual invertebrate taxa (variable 5)	<10% taxa with <75% WUA cf Q_m	≥10% of taxa with <75% WUA cf Q_m	≥25% of taxa with <75% WUA

The risk assessment was conducted as follows for each of the above variables (See Figure 5.1 for worked example):

- WUA as it varies with Q is normalised so that the maximum, WUA_m, is 100%
- Q_n can then be read directly from the relevant percentage of WUA_n on the graph (the appropriate percentage for each risk level is indicated in Table 2)

  where

  WUA_n = Weighted Useable (habitat) Area for month of concern
  HA_m = Weighted Useable Area for pre-offtake median flows
  Q_n= Boundary flow for risk level during month of concern (*n)*

5 Results

5.1 Physical Habitat Data

Hydrologic and substrate information was collected for discharges of 0.55 cumecs. Subsequent gauging visits were carried out when the discharge was 1.95 and 5.22 cumecs. Ranges of depth, velocity and substrate at the site are presented in Table 5.1.

Table 5.1 Ranges of depth, velocity and substrate at George River at Yosts Flats

Variable	Range
Depth (m)	0.031 - 1.13
Velocity (m/s)	0 - 0.72
Silt (%)	0 - 60
Sand (%)	0- 100
Gravel (%)	0 - 80
Pebble (%)	0 - 65
Cobble (%)	0 - 70
Boulder (%)	0 - 30
Bedrock (%)	0 - 100

5.2 Biological Data

Seventeen invertebrate samples were successfully taken at Yosts Flat. WUA-Q curves were developed for each of the key taxa listed below (Table 5.2). These curves are provided in Appendix 2.

Table 5.2: Selected taxa for which WUA curves were developed.

Type	**Common name**	**Taxon**	**Lifestage (s)**
Fish	Brown trout	*Salmo trutta*	adults and late 0+
	Jollytail	*Galaxias maculatus*	adults
	Shortfinned eel	*Anguilla australis*	adults
Invertebrates			
Insects	Mayflies	*Baetidae Genus 2*	larvae
		Baetid Genus 1 sp MV4	larvae
		Austrophlebioides spp.	larvae
		Nousia spp.	larvae
		Tillyardophlebia spp.	larvae
		Leptophlebiidae *Genus Z*	larvae
	Caddisflies	*Asmicridea* spp.	larvae
		Ecnomus spp.	larvae
		Notalina spp.	larvae
		Agapetus spp.	larvae
		Conoesucus nepotulus	larvae
		Tamasia variegata	larvae
		Triplectides proximus	larvae
		Taschorema complex	larvae
	Midges	Chironominae	larvae
		Tanypodininae	larvae
		Orthocladiinae	larvae
	Flies	Ceratopogonidae	larvae
		Tipulidae	larvae
	Blackflies	*Austrosimulium furiosum*	larvae
	Beetles	*Austrolimnius* spp.	adults and larvae
		Scirtidae	larvae
		Simsonia leai	larvae
Molluscs	Freshwater bivalve	*Pisidium casertanum*	adults
	Freshwater snail	*Ferrissia tasmanica*	adults
Worms	Freshwater worms	Oligochaeta	adults
Mites	Freshwater mites	Hydracarina	adults

5.3 Risk Analysis

A worked example of the risk assessment process for one variable is shown in Figure 5.1
Results of the risk assessment are provided in tables 5.3. Note that the highest monthly flow required to provide the required quantity of habitat for any variable has been chosen as the flow for each category to ensure that all values are protected.

Figure 5.1 : Worked example of Risk Analysis.

To determine the flow at which there is no risk to adult trout at North Esk River, Watery Plains reach in December (some values excluded for brevity):

1. RHYHAB gives values for WUA as it varies with Q:

Flow	WUA (m^2/m)
0.05	0.94
0.45	2.95
0.85	3.93
1.25	4.63
1.65	5.31
2.05	5.91
2.45	6.2
2.85	6.37
3.25	6.47
3.65	6.53
3.85	6.55

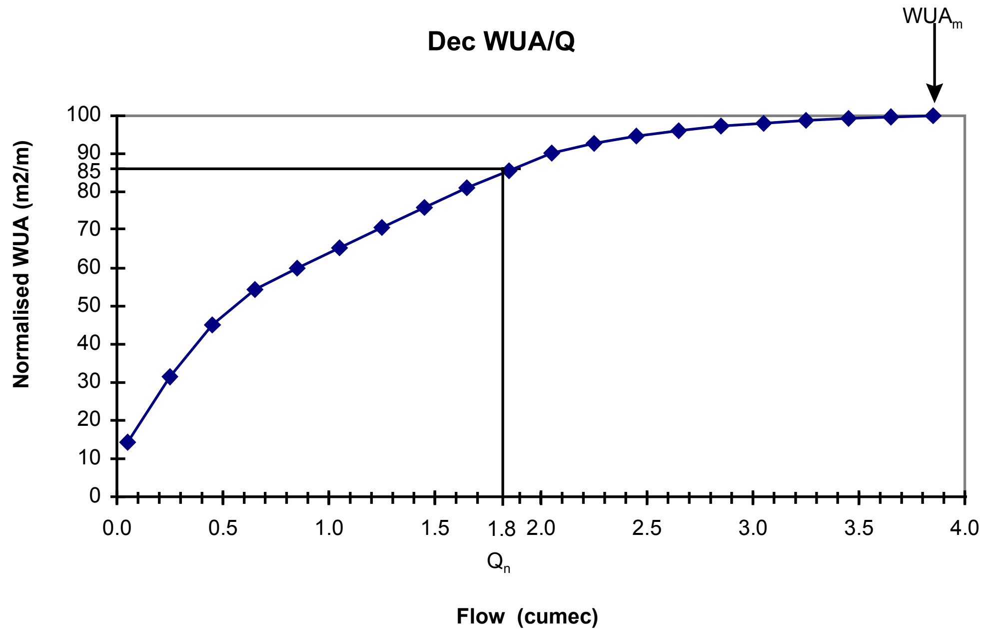
2. This is then normalised so that the maximum, WUA_m, is 100%:

Flow	Normalised WUA
0.05	14.35
0.45	45.04
0.85	60.00
1.25	70.69
1.65	81.07
2.05	90.23
2.45	94.66
2.85	97.25
3.25	98.78
3.65	99.69
3.85	100.00

Figure 5.1 cont:

3. Q_n can then be read directly from the relevant percentage of WUA_n on the graph where:

WUA_d = Weighted Useable (habitat) Area for December
HA_m = Weighted Useable Area for pre-offtake median flows
Q_n= Boundary flow for risk level during month of concern (*n)*



ie. to get the no risk flow, the percentage WUA above 1.8 cumec, there should be no risk to trout adults in the North Esk River, Watery Plains reach in December.

Table 5.3 Full risk analysis by month - Reach 1 (flow in cumecs)

December

Risk Category	No Risk	Moderate Risk	High Risk
Adult Trout	>0.92	0.92 - 0.38	<0.38
0+ Mar Trout	>1.33	1.33 - 1.20	<1.20
G. maculatus	>0.18	0.18 - 0.09	<0.09
Shortfinned eel	>0.27	0.27 - 0.10	<0.10
Macroinvertebrate taxa	>0.96	0.96 - 0.63	<0.63
Flow	>1.3	1.3 - 1.2	<1.2

January

Risk Category	No Risk	Moderate Risk	High Risk
Adult Trout	>0.80	0.80 - 0.30	<0.30
0+ Mar Trout	>1.10	1.10 – 0.26	<0.26
G. maculatus	>0.21	0.21 - 0.09	<0.09
Shortfinned eel	>0.28	0.28 - 0.10	<0.10
Macroinvertebrate taxa	>0.84	0.84 - 0.58	<0.58
Flow	>1.1	1.1 – 0.6	<0.6

February

Risk Category	No Risk	Moderate Risk	High Risk
Adult Trout	>0.68	0.68 - 0.22	<0.22
0+ Mar Trout	>0.32	0.32 - 0.10	<0.10
G. maculatus	>0.25	0.25 - 0.09	<0.09
Shortfinned eel	>0.29	0.29 - 0.10	<0.10
Macroinvertebrate taxa	>0.72	0.72-0.53	<0.53
Flow	>0.7	0.7 - 0.5	<0.5

March

Risk Category	No Risk	Moderate Risk	High Risk
Adult Trout	>0.80	0.80 - 0.30	<0.30
0+ Mar Trout	>1.10	1.10 – 0.26	<0.26
G. maculatus	>0.21	0.21 - 0.09	<0.09
Shortfinned eel	>0.28	0.28 - 0.10	<0.10
Macroinvertebrate taxa	>0.84	0.84 - 0.58	<0.58
Flow	>1.1	1.1 – 0.6	<0.6

April

Risk Category	No Risk	Moderate Risk	High Risk
Adult Trout	>0.92	0.92 - 0.38	<0.38
0+ Mar Trout	>1.33	1.33 - 1.20	<1.20
G. maculatus	>0.18	0.18 - 0.09	<0.09
Shortfinned eel	>0.27	0.27 - 0.10	<0.10
Macroinvertebrate taxa	>0.96	0.96 - 0.63	<0.63
Flow	>1.3	1.3 - 1.2	<1.2

6 Discussion

Before discussing the implications of the risk analysis results, it is important to re-iterate the caveat stated at the beginning of the report. This is that the flows are only appropriate for the individual months for which they have been recommended. However, the ecological integrity of rivers is dictated by hydrological processes operating throughout the year, and if there is further development of the water resource the issue of non-summer flows will require attention and further assessment by DPIWE.

It should also be stressed that an essential part of setting an environmental flow is the monitoring of compliance and environmental benefit. Further assessment may need to be undertaken in the future if monitoring highlights values that are not being met by the negotiated flow regime.

Any risk assessment must be made relative to some reference flow. Here, a reference flow was calculated by adding irrigation offtakes into the existing flow data for the period 1968-1999. In this way the reference flows were the flows that could have been expected if there was no irrigation during this time. Medians have been used for the risk analysis rather than means, due to the effect of high flow events skewing means upward and away from a true measure of the central tendency of the data.

The risk analysis (section 5.3) relates to the values specifically considered, including:

- to maintain sufficient habitat for jollytail, shortfinned eels and brown trout; and
- to maintain sufficient habitat for macroinvertebrate populations found in the George River.

The risk analysis also indirectly assesses other values nominated by the community, namely:

- to maintain suitable in-stream habitat;
- to maintain sufficient flows for fish habitat retention; and
- to maintain fish stocks, including jollytail, shortfinned eels and brown trout.

6.1 Other Values

Phebalium daviesii (St Helens wax flower) is found in the mid-reaches of the George River. This is its only known location in the world, and the species is listed as endangered under *the Threatened Species Protection Act 1995*. All plants occur on the lower flood terraces and spread by vegetative reproduction, thus requiring floods for propagation (Michael Askey-Doran, Resource Management and Conservation Branch, DPIWE, pers. comm.). In addition, the plants require a suitable soil moisture regime, which will be affected by the level of the groundwater table. To date the flow regime is modified only to a small degree by irrigation abstraction over summer, with both winter flood peaks and groundwater replenishment unlikely to be affected by this abstraction. Therefore current flow regime modifications should not be negatively influencing *Phebalium daviesii* at present. However, this species represents one of the most important ecological values of the George River catchments and any future developments of the resource or in the catchment must consider and ensure its protection.

The spawning of brown trout was not investigated as this occurs outside the irrigation period, between April and August (Davies and McDowell, 1996). Similarly, the shortheaded lamprey and the pouched lamprey both carry out their spawning runs into Tasmanian rivers during spring (Potter, 1996), and riverine spotted galaxias spawn in autumn-winter and return to the river as part of the whitebait run during spring (McDowell and Fulton, 1996). Spawning requirements for these species were also not investigated.

The assessment of flow requirements for the spawning of grayling, longfinned eels and freshwater flathead was beyond the resources of this study. Little is known about the spawning of freshwater flathead, but it is known that longfinned eels move into rivers during spring and summer (Beumer, 1996), and that grayling probably spawn during April and May (McDowell, 1996). Habitat preference information is not available for these species to date. Given the low water demand within the catchment and the fact that spawning and rearing of these species is largely outside the irrigation period, abstraction is unlikely to affect these values at present.

6.2 Flow Recommendations

Table 6.1 provides a summary of flows that will provide certain, defined risks to the maintenance of ecological values in the Yosts Flat reach. These risks only apply to this reach (see section 2.2.1 for details of the extent of the reach).

Table 6.1 Flows for each risk category, George River, Yosts Flat Reach (flow in cumecs)

Risk Category	No Risk	Moderate Risk	High Risk
Month			
December	>1.3	1.3 - 1.2	<1.2
January	>1.1	1.1 - 0.6	<0.6
February	>0.7	0.7 - 0.5	<0.5
March	>1.1	1.1 - 0.6	<0.6
April	>1.3	1.3 - 1.2	<1.2

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Appendix 1 The Role of Environmental Flow Assessment in Water Management

Introduction

Australian governments have adopted a set of National Principles for Provision of Water for ecosystems (ARMCANZ & ANZECC, 1996). These principles guide the management of environmental flow regimes across Australia, through the Council of Australian Government's (COAG) water reform agenda (ARMCANZ, 1996). State governments are able to individually adopt a more strategic and accelerated approach to environmental flow assessment and water management.

This section introduces the Tasmanian approach to water management planning. It places the environmental flows program in Tasmania in relation to other stages of developing water management plans. These include:

- the identification of water values by the community and the State government;
- the negotiation and tradeoff of these values that may be required when determining a new flow management regime; and
- an iterative process of monitoring and review of both compliance and environmental benefit of this new flow regime.

The environmental flows program in Tasmania has been structured to allow effective assessment of ecological flow requirements, and constructive negotiation in flow management. Therefore the program has a number of key features, including:

- comprehensive community consultation to identify water values within a catchment;
- comprehensive technical consultation in order to gather information about the river ecosystem and which values need protection;
- the use of the most appropriate environmental flow assessment tool to identify the ecological requirements, given the nature of the stress the river experiences; and
- the provision of a series of options and associated ecological and hydrological risks to assist in any negotiation and tradeoff process that may occur.

The remainder of the section deals with each stage of the water management process that are principally involved in the formulation of a new flow management regime. Other documents such as Fuller and Read (1997), Nelson (1997) and Phillips (1998) have detailed various aspects of the evolving water management process during the current period of water reform in Tasmania, and provide a comprehensive background to the current state of water reform in Tasmania.

The values approach

In Tasmania, environmental flow assessment for each catchment operates within a water value setting framework. This is discussed by Fuller and Read (1997) who suggest a management approach for environmental flow assessment and allocation. Values form a useful basis from which to establish management actions/plans which have broad support. The co-operative approach to the identification of these values by various parties is more likely to achieve the intended outcomes than plans drawn up by any single party (Fuller, 1998).

State resource management and environmental agencies use a common approach in setting catchment values through community consultation. Although the value setting approach for water quantity complements the approach described in the State Policy on Water Quality Management (Government of Tasmania, 1997) on the setting of Protected Environmental Values (PEV's), they are not integrated. Table 1 illustrates the common themes for values in each of these processes.

Table 1 Comparison of water quality and quantity value setting processes

State Water Quality Policy (PEV's)	**Water Management Planning (Water Values)**
Protection of aquatic ecosystems	Ecosystem values
Recreational water quality and aesthetics	Recreational values Aesthetic landscape values
Raw water for drinking supply Agricultural water uses Industrial water supply	Consumptive/non-consumptive uses
	Physical landscape values

The identification of values is a fundamental step in developing water quality guidelines for specific water bodies and Water Management Plans. Water Management Plans are intended to be a vehicle for the open management of water resources in a catchment and contain:

- environmental flow requirements;
- guidelines on water trading;
- agreed plans for sustainable water development; and
- protocols for the implementation of restrictions during drought periods (Fuller, 1998); and
- details of the methodology that will be used to monitor compliance and environmental benefit.

Preliminary values can identify the information gathering needs of each catchment. Typically, they will encompass specific issues which need to be considered in environmental flow assessment, and, to some extent, guide scientific investigations into the requirements of the river in question. They will also contain a review of water quality and a set of allocation constraints which can be considered during water balance modelling. Prioritisation of values within each category is fundamental, as it provides guidance on the values which could potentially be "traded off" during negotiations and hence guidance for hydrologists in investigating water allocation scenarios.

Identification of preliminary values by community consultation

In Tasmania, a focus or stakeholder group from the community is formed to identify and prioritise specific water values within each of the above water value categories. Meetings to identify community values include representatives from different groups within each the community (eg. recreational fishing, farming, environmental, irrigation, local government etc.). These people are sent a letter prior to the meeting, along with documents explaining the value setting approach and a detailed description of the water value categories. The meetings are run by a facilitator who helps the group to identify specific water values under each water value category. They are then are collectively prioritised within each category.

Essentially, the final product is a list of prioritised values important to the focus group of the catchment in question. These preliminary values form part of the basis for negotiation later on in the water management planning process.

Technical values

The community process is complemented by the identification of values (including non-negotiable values) at the state level. State values include issues such as wetlands protected under legislation/agreements, endangered species and important recreational fisheries, etc.

To identify state values, a technical committee is formed which consists of representatives from relevant government agencies and some external institutions. These representatives have expertise in various disciplines related to river ecosystems, such as estuarine ecology, riparian vegetation and wetland ecology. Collectively, they can adopt a holistic approach to identifying values from a scientific perspective. These state values are identified in much the same way as community values; that is in a workshop process and on a catchments by catchment basis.

The group operates on the following terms of reference (Fuller, 1998):

- to determine a set of defined catchments for which water management planning will be completed;
- to develop an agreed process(es) for quantitatively defining catchment priorities according to the stresses placed on their waters, or other special management requirements; and
- to identify water values from a technical and scientific perspective including the non-negotiable values which are implicit in various local, national and international agreements and legislation.

It is anticipated that these technical representatives will provide advice to the state in any negotiation process that may occur.
Both sets of values are normally expected to be tabled in focus group meetings after the environmental flow assessment has been made and negotiation has commenced.

Environmental Flow Assessment

The environmental flows assessment process in Tasmania has been outlined by Fuller and Read (1997). Nelson (1997) provides the major objectives of the DPIWE environmental flows program and its implementation in Tasmania.

These objectives are:

- to prioritise and rank rivers on the basis of the significance of management issues and the level of demands;
- to undertake preliminary work to identify important in-stream requirements (eg. critical flow periods, spawning flows for fish, water quality parameters and significant biotic factors);
- to establish management values and objectives by using a consultative process for each catchment;
- to adopt a desktop approach for low priority rivers; and
- to adopt more detailed field techniques for high priority rivers.

Tasmania has adopted a wide range of environmental flow assessment tools in the past. This has largely been due to the need for the most appropriate methodology to address the environmental requirements of a given catchment. As many studies have addressed catchments in low flow periods, the Instream Flow Incremental Methodology (IFIM) has been used. This method provides a direct, measurable relationship between ecological habitat and flow, and allows direct linkage with hydrological studies and risk assessment. IFIM is recognised internationally as one of the most biologically defensible techniques available, and it allows different parties to negotiate on common ground (Jowett, 1996).

Other methods for environmental flow assessment are reviewed by Nelson (1997). This report provides a comprehensive appraisal of methods used in Tasmania to date, and outlines methods that are likely to be used in future. DPIWE has adopted a position of determining the method of environmental flow assessment on a catchment basis. The method selected will depend largely on what part of the flow regime is affected, and on the environmental requirements of the particular river. On rivers that are largely unaffected by water abstraction, desktop methods will usually be used and a criterion set for when a certain level of water use is reached. Desktop methods aim to maintain the general integrity of an ecosystem by safeguarding riverine habitat to support ecosystem function.

In highly stressed rivers or rivers earmarked for future resource development, more reliable and defensible techniques based on field assessment will be used, and this will usually be accompanied by an evaluation of the risk of failure to achieve environmental flows.

Tradeoff of environmental outcomes

Naturally, the allocation of water to meet ecological values is not independent of the need to provide water to meet other values (i.e. consumptive/non consumptive). As a result, models of the resource are required to assess the effects of allocation strategies (Fuller, 1998).

Water is a dynamic resource and clearly there will be circumstances in which there is insufficient water to meet all demands. The final outcomes of environmental flow assessment should include a series of recommendations of different flows and the ecological risks associated with the failure to meet each flow.

In addition, hydrological models can assist water managers to quantify the risk associated with resource allocations. The tradeoff process relies on the adoption of a set of priorities which are attributable to the water values for a given catchment. The aim at this stage is to move from the preliminary values to clear management objectives which are needed to develop a draft water management plan for the catchment.

If it is determined that the river system is not over allocated then the recommendations may go directly into the water management process. Only if the system is found to be over allocated will a negotiation process with potential tradeoff need to occur. This will take place between the committee that identified the values and the Water Manager. Once negotiation is finalised, the allocation of water for the environment will be included in the draft water management plan for the river.

It is clear that in some instances there should be a relatively smooth tradeoff process, and in other instances resolution may not be reached. Nevertheless, the resource management agency has the task of developing a balanced water management plan in the interests of all users and is responsible for negotiation between all parties involved.

Public consultation and ratification of the plan

Once the negotiation with the focus group and the tradeoff process has occurred, the draft management plan can be developed. This plan will then be exposed to full public consultation and revision, before formal implementation as a statutory plan. Water management plans will be implemented as part of Tasmania's integrated Resource Management and Planning System (RMPS) and subject to appeal through the Resource Management and Planning Tribunal.

Monitoring

Another component of the plan will identify the level and type of monitoring required in implementation of the plan. This monitoring will then act as a clear indicator of the performance of the Water Manager and as a test of any environmental benefit or detriment to the river ecosystem. Realistically, there will be a tradeoff between what can be achieved and the resolution of monitoring required to understand the complexities of the ecosystem.

Monitoring can be divided into two areas: (i) compliance monitoring; and (ii) monitoring environmental benefit. Compliance monitoring will largely rely on the operation of stream gauging stations and water quality monitoring networks. This type of data can be directly assessed against the flow and water quality requirements of the Water Manager. Monitoring of environmental benefit/status is more difficult and the State is currently developing a combination of approaches for this purpose.

Firstly, the ecological models of river health being developed under the National River Health Program provide a broad range of tools for the assessment of impacts. These tools (based on macroinvertebrate sampling) are useful for identifying changes over time but have some problems in terms of sensitivity. These problems may be overcome to some extent by:

- the creation of catchment specific models rather than the regional models used to date;
- the use of lower levels of taxonomic identification (species);
- the implementation of quantitative rather than qualitative sampling protocols;
- the development of rank abundance models which are more sensitive to hydrological disturbance than the current models adopted by the state.

Secondly, indices of stream/river condition are being adopted in Victoria and Queensland as tools for qualitative assessment of environmental condition (Nelson, 1999). These tools are not designed specifically to monitor or assess hydrological impacts and are aimed at assessing overall catchment condition. However, they may provide another source of information which can be used in a broad management sense. Such indices may be useful in monitoring rivers that are not subject to large amounts of water abstraction.

Thirdly, a performance reach based approach (Sedger, 1997) is being adopted in NSW. This approach provides a more quantitative assessment of ecological condition in gauged reaches, thus establishing a more accurate assessment of ecological health and its variation with flow. A similar but more comprehensive approach is currently being carried out in the Mersey River Catchment. However, these monitoring protocols are labour intensive and very costly. Hence this approach is likely to only be used in situations where a river system is significantly impacted, or where there are special needs.

Finally, if ecological values and objectives can be specified with sufficient clarity, it will be possible to monitor changes in that part of the ecosystem. For example, if protection of an endemic species population is a management priority, then monitoring of population dynamics would provide a direct measure of management actions (assuming all other factors are equal). This type of monitoring may need to be undertaken by other agencies either as part of their normal actions or alternatively at the expense of the water manager.

It is intended that water management plans will have a finite life, of about 5 years, and be subject to review after this period.

Summary of environmental flow setting procedure

DPIWE has attempted to place environmental flow assessment in a series of defined steps that:

- involve consultation with the community within each catchment and the state agencies;
- carry out the most appropriate environmental flow assessment relevant to the particular requirements or stresses currently on the catchment; and
- provide a series of options to the parties involved in any negotiation that may take place, in order to carry out more informed decision making and negotiation.

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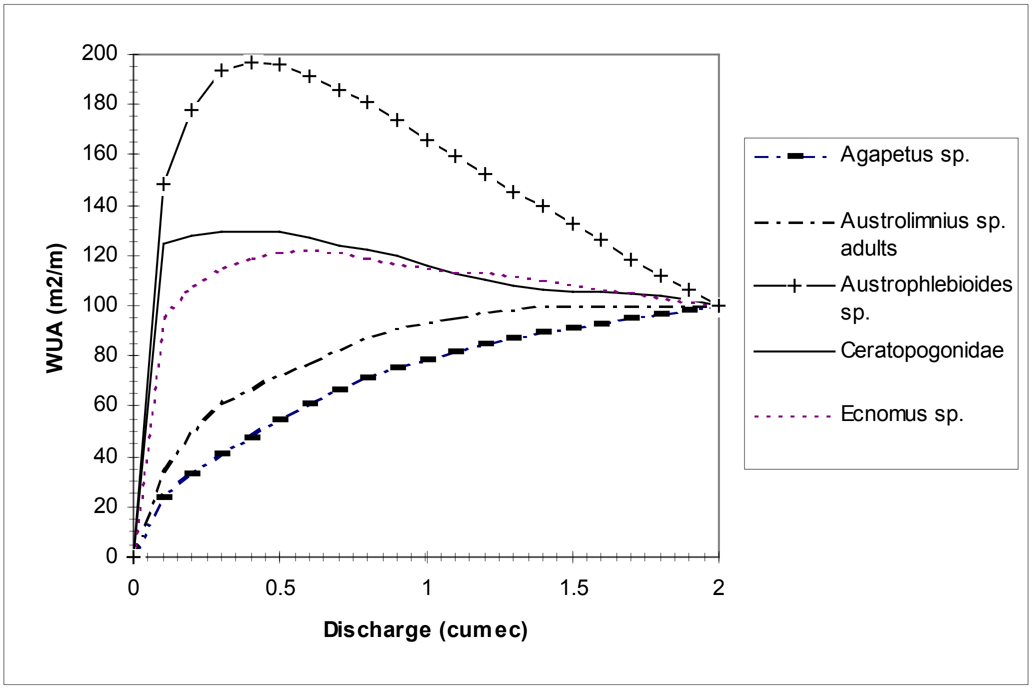
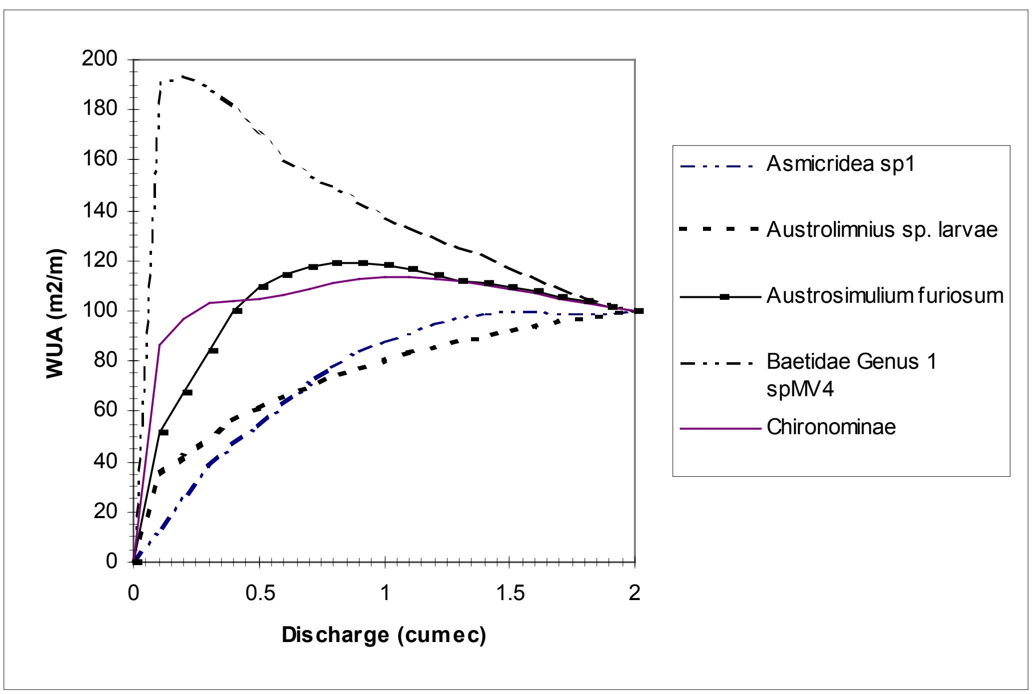
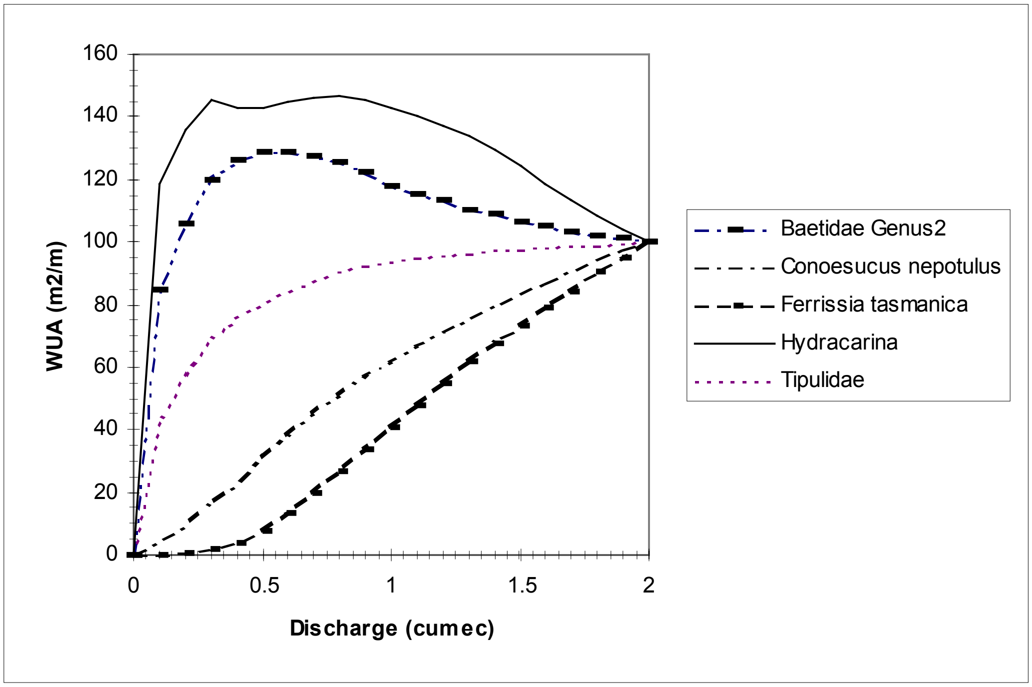
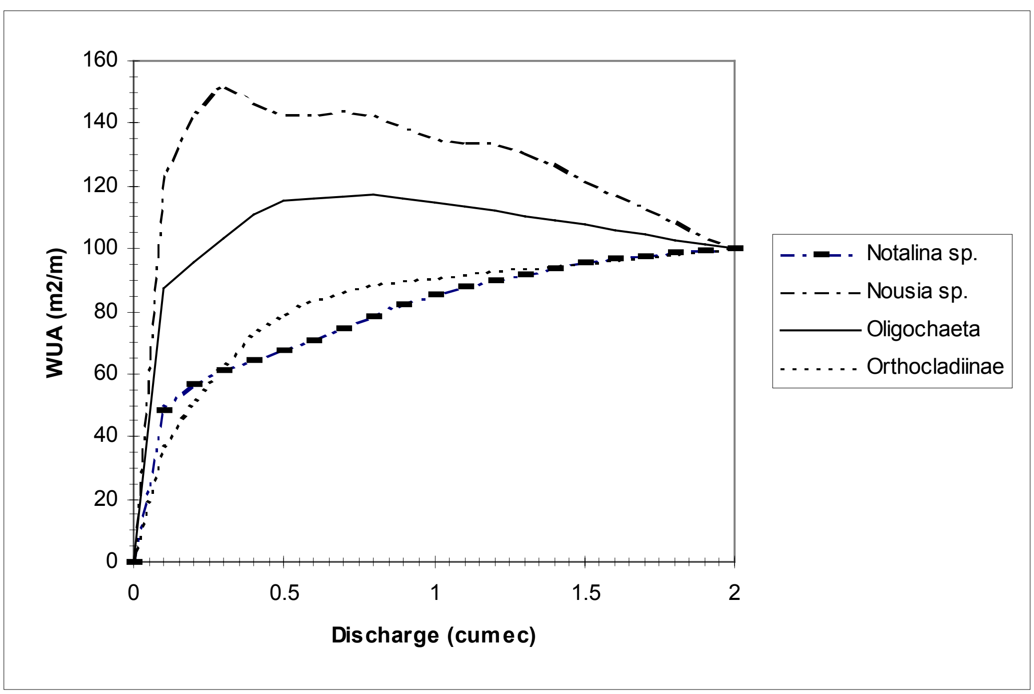
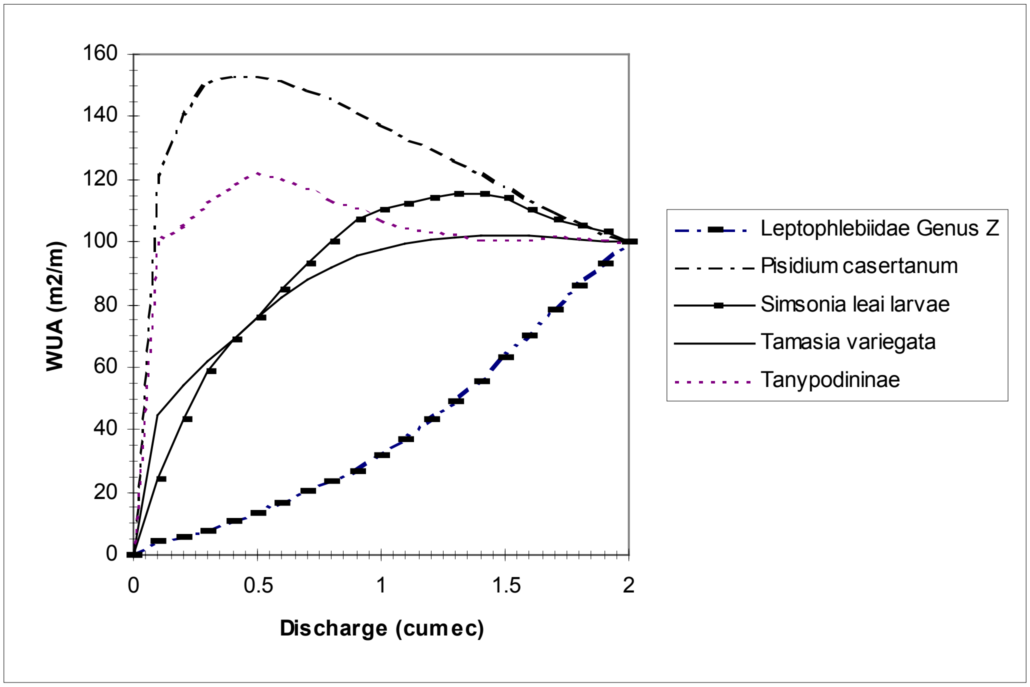
Appendix 2 Weighted Useable Area (WUA) curves for the George River






160
140
120
100
80
60
40
20
0
WUA (m2/m)
0
0.5
1
1.5
2
Discharge (cumec)
Baetidae Genus2
Conoesucus nepotulus
Ferrissia tasmanica
Hydracarina
Tipulidae


160
140
120
100
80
60
40
20
0
WUA (m2/m)
0
0.5
1
1.5
2
Discharge (cumec)
Notalina sp.
Nousia sp.
Oligochaeta
Orthocladiinae



160
140
120
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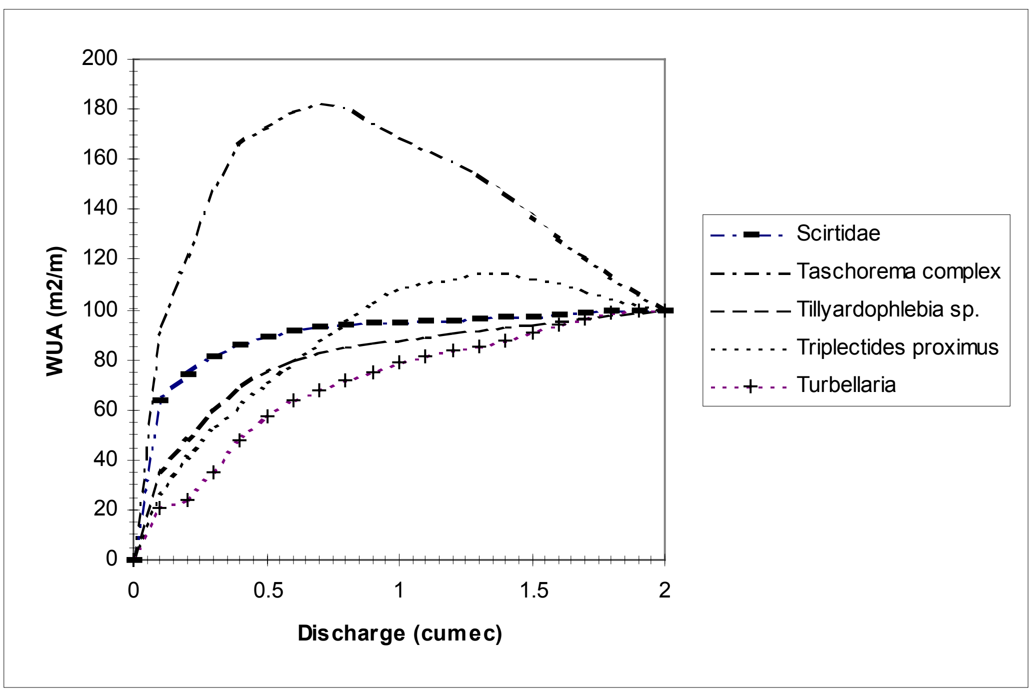
40
20
0
WUA (m2/m)
0
0.5
1
1.5
2
Discharge (cumec)
Leptophlebiidae Genus Z
Pisidium casertanum
Simsonia leai larvae
Tamasia variegata
Tanypodininae



200
180
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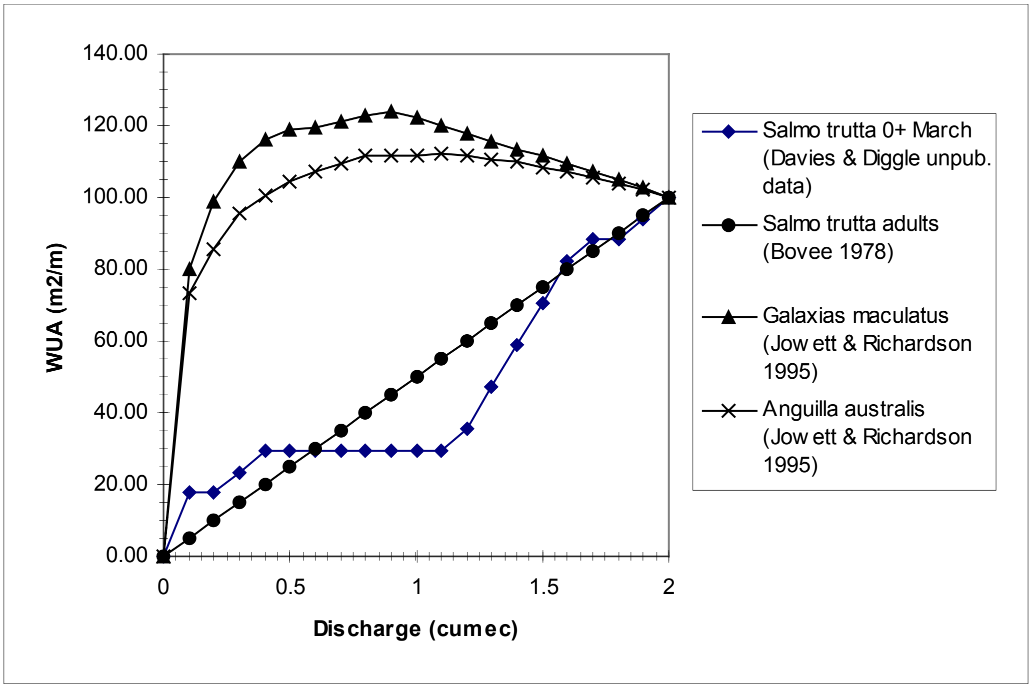
WUA (m2/m)
0
0.5
1
1.5
2
Discharge (cumec)
Scirtidae
Taschorema complex
Tillyardophlebia sp.
Triplectides proximus
Turbellaria



140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
WUA (m2/m)
0
0.5
1
1.5
2
Discharge (cumec)
Salmo trutta 0+ March (Davies & Diggle unpub. data)
Salmo trutta adults (Bovee 1978)
Galaxias maculatus (Jowett & Richardson 1995)
Anguilla australis (Jowett & Richardson 1995)

Richard Norris â€“ River ecological condition assessment Expert Reference Panel Final Report to the Project Board â€“ February 2002 2 CONFIDENTIAL Environmental flow requirements for the River Murray System TABLE OF CONTENTS